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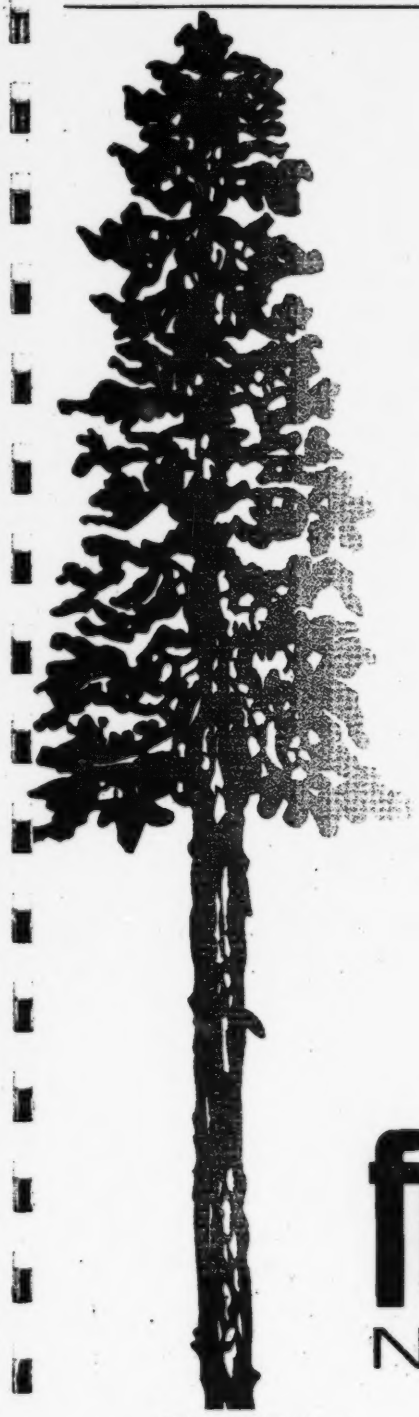

Water Quality Monitoring of a Small Spring Following Forest Harvesting

David R. Gluns RPF
and
Kim Green PGeo

Technical Report TR-007

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Forest Sciences Section
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518 Lake Street
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June 1994

ABSTRACT

In July 1986, a spring used for domestic consumption was discovered 680 meters below a stand of timber to be clearcut. The spring, known as Strom Spring, was unlicensed and therefore did not show up in a referral to B.C. Ministry of Environment, Water Management Branch. Immediate concern was raised about the potential impact of the harvesting and site treatment on water quantity and quality. After an assessment, Ministry of Forests hydrologists determined there was no evidence that water quantity would be affected. However, changes in water quality were not known. In response to the lack of information on water quality in this area, the Kootenay Lake Forest District requested a water quality monitoring program to assist in the evaluation of the harvesting effects on Strom Spring. Water samples were taken monthly from October 1986 to November 1988 during which time the block was harvested and burned. Sixteen chemical parameters were monitored. Calcium, hardness and conductivity showed increasing trends during the monitoring period. At times, iron and total hardness concentrations exceeded drinking water quality standards. A number of factors including the underlying bedrock geology and the relatively short sampling period make it difficult to attribute increasing concentration trends or high concentrations to up-slope harvesting activities.

ACKNOWLEDGEMENTS

This study was initiated with the financial support of the Kootenay Lake Forest District. Doug McMullin provided information regarding timber harvest and burning activities. Tom Braumandl of the Nelson Forest Region provided ecological and soil information. Emilee Fanjoy, Nelson Forest Region, assisted with the water sampling program. Reviews of an earlier draft of this report were made by Andrea Ryan, Environment Canada, Barry Willoughby, B.C. Ministry of Health, Steve Chatwin and Dave Toews, B.C. Ministry of Forests and Bruce Holmes, B.C. Ministry of Environment. Permission to sample the spring was given by the land owners - Mr. and Mrs. Strom.

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1 INTRODUCTION

The impact of forest harvesting activities on small water sources is a concern to those utilizing these water sources for domestic and irrigation purposes. Their concern is for the maintenance of both water quality and water quantity.

Water quantity studies summarized by Bosch and Hewlett (1982) report unchanged or increased amounts of water following forest removal. Results are dependent on the amount of drainage area affected by forest removal. Generally, removal of timber from less than 30% of total drainage area does not cause an observable change in water yield. When more than 30% is removed, increased water yields are generally proportional to the area harvested.

Alternatively, the results of studies assessing the impact of forest harvesting activities on water quality are highly variable. Results depend upon the location, climate, topography, geology, soils, method of logging, post-logging treatment, and water source. Hence, in dealing with local resource issues, the effect on water quality from forest harvesting is a greater unknown than effects on water quantity.

In southeastern B.C., little research has been conducted on the impacts of forest harvesting activities on water quality, although several studies do exist. Hetherington (1976) monitored water quality the second year following clearcutting 25% of the forest in Dennis Creek watershed in the Okanagan Valley. He noted significant increase in water colour and minor increases in potassium, sodium chloride, specific conductivity, total organic carbon and dissolved solids. No changes were detected in total Kjeldahl nitrogen, nitrate, total phosphorus, magnesium, alkalinity, pH, sulphate or total inorganic carbon. A study of water quality following a major wildfire and salvage logging in the East Kootenays reported increased concentrations of nitrate-nitrogen, calcium, magnesium, total nitrogen and total phosphorus, as well as increases in conductivity, total alkalinity, and pH (Gluns and Toews, 1989). In another East Kootenay study where salvage logging of mountain pine beetle infested stands occurred, no differences in concentrations of suspended sediments, nutrients, metals or major ions were measured following logging (Smith et al. 1985). In nearby Idaho, work by Snyder and others (1975) shows increases in specific conductivity, bicarbonate, sulfate, calcium and magnesium at sites immediately below clearcuts. These studies demonstrate that changes in water quality occur as a result of forest removal and site treatment.

Study results such as those discussed above allow managers to evaluate the possible effects forest harvesting will have on water quality. However, the dependance of water chemistry on location makes it difficult to apply the results of a specific study to a larger area. In most locations the lack of baseline data prohibits any definitive projections as to water quality changes. As well, the majority of studies evaluating water quality changes off site as a result of forest harvesting activities, monitor surface water with little effort to evaluate ground water or spring water changes.

Following the development of timber on Pilot Point near Crawford Bay, B.C., a spring used for

domestic consumption was discovered 680 meters below a stand of timber to be clearcut. The spring, known as the Strom Spring, was not licensed and hence did not show up on the referral to Water Management Branch for the timber development. Immediate concern was raised about the potential impact of the harvesting and site treatment on water quantity and quality. In a review of the situation in July 1986[1], there was no evidence that water quantity would be affected. However, changes in water quality were not known. In response to the lack of information on water quality in this area, the Kootenay Lake Forest District requested a water quality monitoring program to assist in the evaluation of the harvesting effects on Strom Spring.

The objectives of this study are to:

1. monitor water quality in a spring located downslope from clearcut timber harvesting and subsequent slashburning;
2. assess the conformance to Guidelines for Canadian Drinking Water Quality (Federal-Provincial Subcommittee on Drinking Water, 1989) and other suggested guidelines and;
3. assess if changes in the levels of various water quality parameters occur over time.

2 STUDY AREA

2.1 Location and Physiography

Strom Spring is approximately 3 km southeast of the village of Crawford Bay (Figure 1). Located at an elevation of 576 meters, the spring is on an east facing slope draining into Crawford Bay -- a large bay off the main Kootenay Lake. The large peninsula on which the spring and the timber development is situated ranges in elevation from lake level (532 m) to a height of approximately 990 m.

Strom Spring is a small contact spring brought to the surface through excavation of soil to a meter in depth. This excavation in turn forms a holding pond for water. A 15 cm pipe transports the water from the collection pond to a single household 220 meters downslope. There is an overflow channel allowing excess water to run out of the pond. Water drains from the spring's pond year round but is more noticeable during the snowmelt period. Due to the configuration of the intake and the pond itself, no attempt was made to take flow measurements.

Drainage and recharge area for the spring is difficult to interpret based on ground surface features. There are several distinct gullies leading up to the cutblock. Surface water is intermittent in these gullies and water appearance on the soil/duff surface is seasonal. Additionally, near the height of land is McGregor Lake (elevation 832 m) which may be the

1. Gluns, D.R. 1986. An assessment of the potential impact of small business sale A25681 on B. Strom's water supply. Unpublished memo.

ultimate source of subsurface water for Strom spring. McGregor Lake has an outlet draining surface water north of the spring to Crawford Bay.

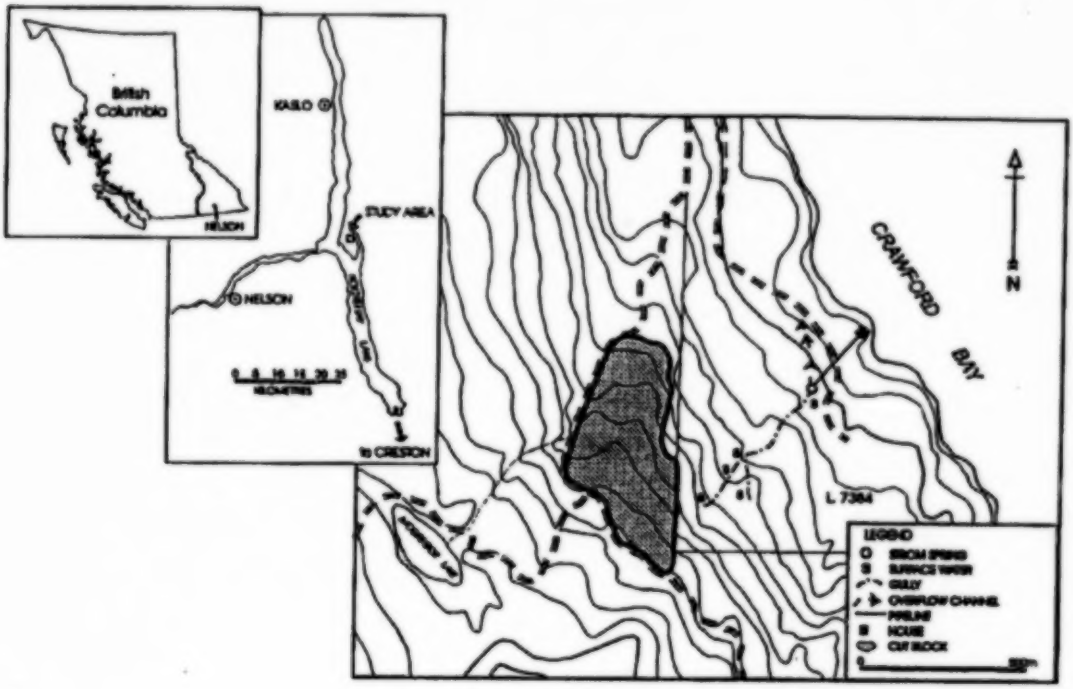

Figure 1. Location of study area.

2.2 Soils and Vegetation

The study area lies within the Dry Warm Interior Cedar - Hemlock (ICHdw) biogeoclimatic subzone (Braumandl and Curran, 1992). Predominate commercial tree species by percentage include Douglas-fir *Pseudotsuga menziesii* (75%), western larch *Larix occidentalis* (20%), and western white pine *Pinus monticola* (5%). The understory consists of western redcedar *Thuja Plicata* along with minor amounts of the major tree species. Vegetation species includes *Rhytidiadelphus, Chimaphila, Clintonia, Linnaea, Alnus, Lonicera,* and *Rosa.*

The soils in the cutblock are derived from mixed diorite and marble bedrock and overlying glacial till. Outcrops of both rock types occur in the upper portion of the cutblock. Sandy, gravelly, glaciofluvial material is exposed locally in the block. Soils in the cutblock are classified as Eutric Brunisols (Ag. Can. Expert Committee on Soil Surv. 1987). Soil textures are sandy loams with a range of 30 to 50% coarse fragments (predominantly subangular gravels). Detailed analysis of a soil profile is presented in Appendix I.

The soils near Strom spring are derived from marble bedrock. The parent material is slope wash fluvial material and is influenced by carbonate rich seepage waters. The soils are classified as Orthic Gleysol (Ag. Can. Expert Comm. Soil Surv. 1987). The soil is calcareous to the soil surface (Ph>7.0 as indicated by fizz with 10% HCl). Soil textures are sandy loam with about 20% gravels.

2.3 Climate

The local climate is strongly influenced by Kootenay Lake. Based on 30 year normals (the true mean obtained in the 30-year sample record) for Crawford Bay (elevation 530 m), an average of 941 mm of precipitation falls throughout the year. Of this, about 30% occurs as snow from November to April. Due to the warmer temperatures of the area, snow accumulations do not amount to much as there is continuous melt throughout the season. The Crawford Bay climate station is currently not in operation and climate records for the period of study were inferred using data from Creston (66 km south), Kaslo (29 km north) and Harrop (16 km west). Monthly precipitation and air temperatures recorded during the water sampling period are presented in Figure 2.

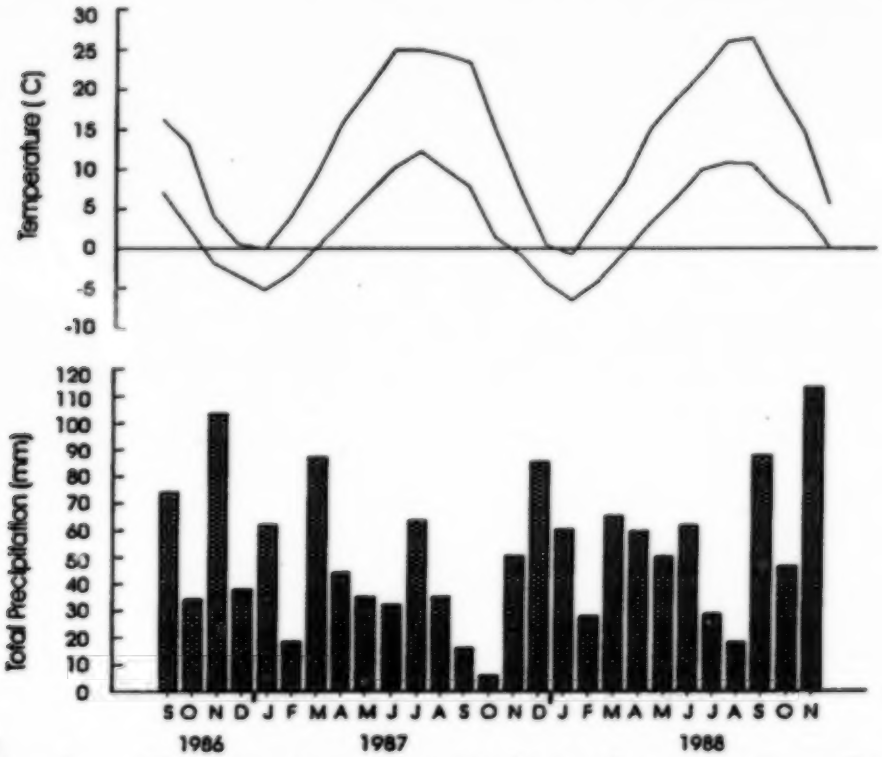

Figure 2. Monthly average maximum and minimum air temperatures as well as monthly total precipitation during the water quality study period.

2.4 Logging History

Timber harvesting and slashburning were carried out over a two year period. Clearcut logging began during August 1986 with 2 ha and expanded 5 ha further in October 1986. During September 1987 an additional 5 ha were logged to bring the total to 12 ha. Slash piles were burnt in the fall of 1987. During July 1988 the block was broadcast burned to prepare the site for spring 1989 planting of larch and lodgepole pine. The proximity of harvesting to the spring is shown in Figure 1.

In addition to the above harvesting, on-site observations indicate historical selective logging took place on Lot 7384, Kootenay District, immediately above and around the spring. Records are not available for this logging.

3 METHODS

3.1 Data Collection

To assess water quality from Strom Spring, water samples were taken monthly from October 1986 to November 1988. Samples were taken within a few days of the beginning of each month.

The environmental lab carrying out the analysis supplied 4 L and 500 mL polyethylene containers for nutrient and metal samples respectively. Samples were taken using the "grab" technique (Ponce 1980) and shipped on ice to the lab. Samples were never more than 24 hours in transit.

Water quality parameters selected for analysis are those suspected to be influenced by forest harvesting and parameters of concern in water used for domestic consumption (Federal-Provincial Subcommittee on Drinking Water, 1989). Specific parameters, the detection level, and the method of analysis are in Table 1.

3.2 Analysis

Data analysis involved comparing measured values with aesthetic objectives and maximum acceptable concentrations as specified in the Canadian Drinking Water Standards (Federal-Provincial Subcommittee on Drinking Water, 1989). Other sources of acceptable levels were utilized for reference for those parameters not listed in the Standards (B.C. Ministry of Health, 1982; McNeely et al., 1979) Summary statistics, seasonality and trend analysis were preformed using WQSTAT II -- a water quality statistics program prepared by Colorado State University for the analysis of water quality data. Summary statistics involve computing the maximum, minimum, mean and standard deviation for each parameter. Seasonality is evaluated using the Kruskal-Wallis test with a 90% confidence interval. It checks for significant seasonal variation, i.e., a predictable change in water quality with time of year. Trend analysis determines the significance of an increase or decrease in concentration over time. The analysis uses the Kendall-Tau test which Ward et al. (1988) report to be as powerful as the t-test for significance of linear trend.

The significance level chosen for the test is 0.10, corresponding to a confidence interval of 90%. The test evaluates the null hypothesis (Ho) that no change has occurred with the alternate hypothesis (Ha) that change has occurred.

TABLE 1. Specific chemical parameters analyzed along with the detection limits and the analytical method employed.

Chemical Parameter	Detection Limit (mg/L)[1]	Laboratory Method[2]
Alkalinity, Total	0.5	Automated electrometer
Calcium	0.02	
Hardness, Total	[3]	Calculated: based on Ca and Mg concentrations
Iron	0.01	
Magnesium	0.02	
Nitrogen: Ammonia	0.005	Automated phenate
Nitrogen: Kjeldahl	0.01	Block digestion followed by automated colourimtric analysis
Nitrogen: Organic	0.01	Calculated: kjeldahl minus ammonia nitrogen
Nitrogen: Nitrate plus nitrite	0.02	Automated cadmium reduction
Nitrogen: Total	0.01	Calculated: kjeldahl plus nitrate/nitrite
pH	0.1	Electrometer
Phosphorus, Total	0.003	Digested automated ascorbic acid reduction
Potassium	0.1	Auto. flame emmission
Sodium	0.5	Auto. flame emmission
Specific Conductance	1 µS/cm	Conductivity meter corrected to 25O
Turbidity	0.1 NTU	Nephelometric method

[1] except for measures of pH, conductivity, and turbidity. Units for these measures are indicated.
[2] all methods are found in American Public Health Association (1985).
[3] minimum detection level dependent upon the detection of the calculated components.

4 RESULTS

Water quality was measured on 26 separate days from October 1986 to November 1988. This covers the period of time when timber was removed from the upslope cutblock and the area was subsequently prepared for planting through slashburning. Table 2 presents summary statistics as well as comparisons to Canadian Drinking Water Standards (Federal-Provincial Subcommittee on Drinking Water, 1989) for each of the parameters measured in water from Strom Spring. Additional standards from other sources are included for purposes of comparison. A complete listing of the data is provided in Appendix II.

4.1 Calcium, Magnesium and Total Hardness

Water hardness is governed by the amount of magnesium and calcium salts, in combination with bicarbonate and carbonate (temporary hardness) and with sulphates, chlorides, and other anions of mineral acids (permanent hardness) (Wetzel, 1975). Total water hardness above 180 mg/L is considered very hard, whereas water with values less than 30 mg/L is referred to as very soft. Values in Strom Spring ranged from 174 to 264 mg/L with an average of 215 mg/L, putting it in the very hard range.

TABLE 2. Water quality summary for Strom Spring in relation to established acceptable and objective levels in water used for domestic consumption.

Water Quality Parameter[1]	Strom Spring Concentrations			Drinking Water Standards[2]	
	Mean	Minimum	Maximum	MAC[3]	AO[4]
Alkalinity, Total	196	163	219	30-500[a]	
Calcium	70.2	55.9	88.1	200[c]	75[a]
Hardness, Total	215	174	264	200[a]	80-100[a]
Iron	0.04	<0.01	0.34	0.3[b]	≤0.05[b]
Magnesium	9.6	8.4	10.8	150[c]	50[c]
Nitrogen: Ammonia	<0.005	<0.005	0.007	0.5[a]	0.01[a]
Nitrogen: Organic	0.03	<0.01	0.07		
Nitrogen: Nitrate plus nitrite	<0.02	<0.02	0.02	10[a]	≤0.001[b]
Nitrogen: Total	<0.05	<0.03	<0.09		
pH	7.8	7.1	8.2		
Phosphorus, Total	0.005	<0.003	0.033	0.2[c]	
Potassium	1.9	0.6	2.2		
Sodium	1.5	1.1	1.7		≤200[a]
Specific Conductance	418	360	470		
Turbidity	0.7	0.4	1.2	1[a]	≤5[a]

[1] all values in mg/L except pH, specific conductance (µS/cm) and turbidity (NTU).

[2] standards are employed from various sources as follows:

[a] Federal-Provincial Subcommittee on Drinking Water (1989).

[b] B.C. Ministry of Health (1982).

[c] McNeely et al.(1979).

[3] maximum acceptable concentration. These are established for substances known or suspected to cause adverse effects on health.

[4] aesthetic objectives. These apply to subetances or characteristics of drinking water which can affect its acceptance by consumers or interfere with practices for supplying good water.

Total hardness is calculated by multiplying the concentrations of calcium and magnesium by a factor to obtain equivalent calcium carbonate and summing the CaCO3 concentrations (American Public Health Association, 1985). Therefore, total hardness can be used as an integrator of both calcium and magnesium. In Strom Spring, hardness exhibits strong seasonality. It also is significant with respect to an increasing trend with time. When both calcium and magnesium are separated out, magnesium does not show this seasonality nor does it show a significant trend with time. However, calcium does show both these trends and is responsible for the hardness results. Figure 3 illustrates the trend for total hardness.

Typical calcium values are less than 15 mg/L, while waters close to carbonate rocks may range from 30 to 100 mg/L (McNeely et al. 1979). Values for calcium in the spring ranged from 56 to 88 mg/L with a mean of 70 mg/L.

Magnesium concentrations are generally low with measured values from 8 to 11 mg/L. The suggested maximum acceptable concentration of 150 mg/L was established by Department of National Health and Welfare (1969) based on palatability with an objective level of 50 mg/L established. Magnesium is not reported in the new drinking water standards.

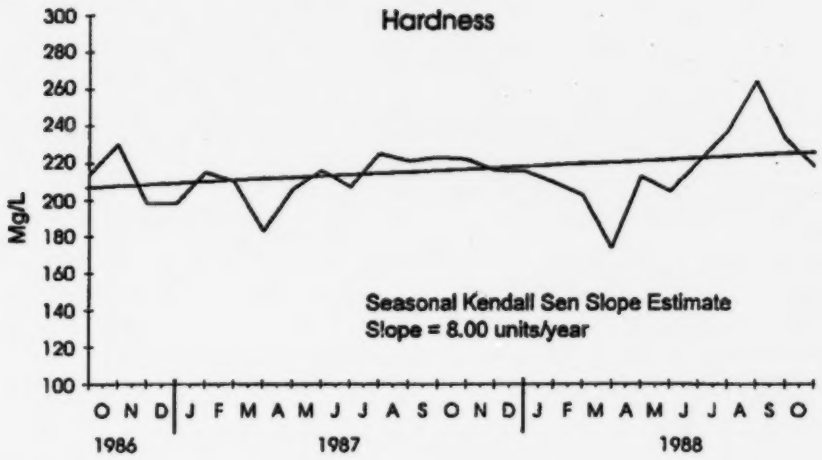

Figure 3. Trend analysis for total hardness depicting the significant increasing trend during the sampling period.

4.2 Iron

Iron is highly objectionable for drinking water because of its bittersweet astringent taste (McNeely et al., 1979). Drinking water concentrations of less than 0.05 mg/L are more palatable. Standards are set for objective levels of 0.3 mg/L. Measures of iron in the Strom Spring ranged from less than 0.01 to 0.34 mg/L with an average of 0.04 mg/L. Standards were exceeded on one sampling date. Iron did not exhibit seasonality nor did it show a significant trend with time during the sampling period.

4.3 pH

The pH of the spring varied from 7.1 to 8.2 with an average of 7.8. These values are within the suggested range recommended for drinking water standards. Seasonality of pH with time of year is not significant nor is any increasing or decreasing trend of values during the sampling period.

4.4 Potassium and Sodium

Both potassium and sodium are alkali metals with similar chemical characteristics except for their weathering. Concentrations of potassium in natural water surface waters seldom reach 20 mg/L and are generally less than 10 mg/L (McNeely et al., 1979). In Strom Spring, potassium ranged from 0.6 to 2.2 mg/L with a mean of 1.9 mg/L. Potassium shows a significant seasonality component but had no trend through the sampling period. Sodium ranged from 1.1 to 1.7 mg/L and like potassium had significant seasonality associated with it. It did not exhibit any trend through the sampling period. All natural waters contain some sodium. Concentration in water ranges from 1 mg/L to 100 000 mg/L. A standard of less than or equal to 200 mg/L is established

for Canada.

4.5 Specific Conductance

Specific conductance (conductivity) is a numerical expression of a water's ability to conduct an electrical current. Conductivity of water is dependent on its ionic concentrations and temperature (McNeely et al., 1979). Specific conductance provides a good indication of the change in water composition. In natural water, conductivity can range from 50 to 1500 µS/cm. The range in Strom Spring is 360 to 470 µS/cm with a mean of 361 µS/cm.

No seasonality exists to conductivity indicating it is not affected by intrusions of water from snowmelt. However, a trend analysis indicates that conductivity significantly increased over the period of monitoring (Figure 4).

In this study conductivity correlates well with total hardness (r^2=0.65) and with filterable residue (r^2=0.87). Filterable residue is residue remaining after a sample has been passed through a standard glass-fibre filter and dried to a constant weight. Filterable residue is analogous to dissolved solids.

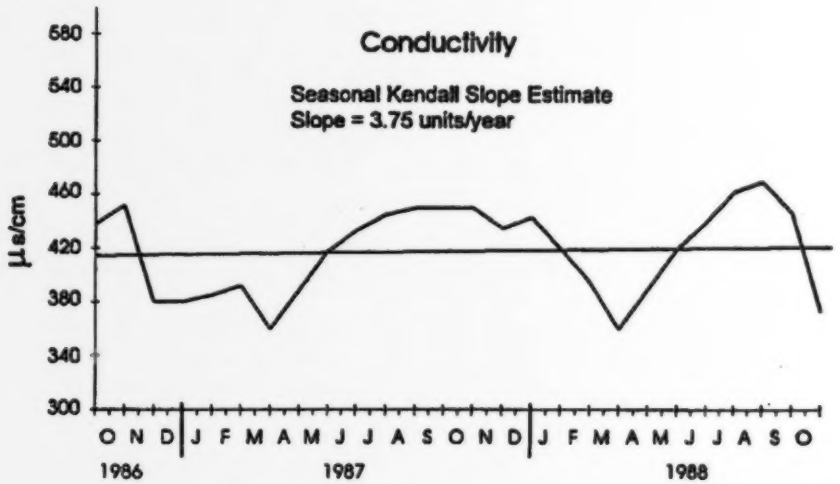

Figure 4. Trend analysis for specific conductivity.

4.6 Total Alkalinity

Total alkalinity measures the presence of carbonates, bicarbonates and hydroxides -- the water's capacity to neutralize an acid. Measured values range from 163 - 219 mg/L with an average of 196 mg/L. Alkalinity values in the range of 30 to 500 mg/L are acceptable. Higher alkalinity values are attributable to carbonate hardness (McNeely et al. 1979) as is the case in this spring.

Seasonality or trends with time are not significant (Figure 5).

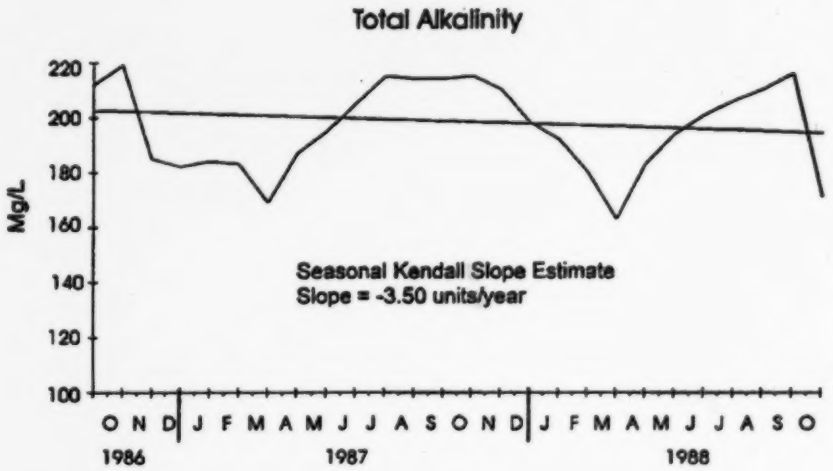

Figure 5. Trend analysis for total alkalinity.

4.7 Total, Organic, Ammonia and Nitrate - Nitrogen

There exists numerous forms of Nitrogen of which the important ones in water are reported here.

Ammonia is the most reduced inorganic form of nitrogen in water and represents only a small component of the total nitrogen cycle. Ammonia contributes to the fertility of a water since nitrogen is an essential plant nutrient. Concentrations are generally low in groundwaters because it adsorbs to soil particles and clays and is not leached readily from soils. Natural waters typically contain concentrations of less than 0.1 mg/L (McNeely et al., 1979). Values ranging from less than 0.005 to 0.007 mg/L occur in Strom Spring with most values less than the detection limit of 0.005 mg/L. The Department of National Health and Welfare (1969) suggests that values should not exceed 0.5 mg/L.

Nitrate (NO_3-) is the principal form of combined nitrogen found in natural waters. The highly soluble nitrate ion, which is the most stable form of combined nitrogen in surface waters, results from the complete oxidation of nitrogen compounds. Nitrification (conversion of ammonia to nitrite then nitrate) is the principal process in the nitrogen cycle. Although surface waters may contain more than 100 mg/L, they rarely contain values over 5 mg/L and often less than 1 mg/L of nitrate. High nitrate values can decrease the blood's capacity to carry oxygen through the body. This is important with infants who may develop "methaemoglobinaemia" resulting from high nitrate intake. Guidelines for Canadian Drinking Water Quality (Federal-Provincial Subcommittee on Drinking Water, 1989) specifies a maximum acceptable concentration of 45.0 mg/L as nitrate (10.0 mg/L as nitrate-nitrogen as measured in this study). Values in Strom Spring are below

detection level except on one occasion where 0.02 mg/L was measured.

Organic nitrogen is an organically bound form of nitrogen that is the most reduced form. In surface and groundwater it is very low, typically less than 0.01 mg/L (McNeely et al., 1979). Organic nitrogen results from both the inflow of nitrogenous debris from a watershed and the normal biological activities in a stream. Organic nitrogen *per se* is not of concern to human health. Measures in the Strom Spring ranged from below detection level to 0.07 mg/L.

Total Kjeldahl nitrogen is calculated by the conversion of free ammonia and organic nitrogen to ammonium bisulphate. No specific guidelines are established for drinking water. During the study values ranged from less than 0.03 to 0.09 mg/L.

Neither trends nor seasonal effects could be observed for any of the nitrogen forms reported here because most of the values were below detection limits.

4.8 Total Phosphorus

Phosphorus is rarely found in significant concentrations in surface water, since it is actively taken up by plants (McNeely et al., 1979). Total phosphorus concentration in uncontaminated lakes is in the order of 0.01 mg/L. A concentration of 0.2 mg/L phosphate (as PO_4) is defined as acceptable limit for drinking water (Department of National Health and Welfare, 1969). When sufficient nitrogen compounds are present, phosphorus concentrations above 0.1 mg/L in water may prove troublesome by promoting the development of aquatic plants, bacteria and algae.

In Strom Spring, concentrations range from less than 0.003 to 0.033 mg/L with an average of 0.005 mg/L. Values are extremely low and are not of significant consequence. No seasonality or trends are apparent in the data.

4.9 Turbidity

Turbidity values were obtained during the first eight sampling periods. Values are low ranging from 0.4 to 1.2 NTU. As the sampling is carried out in a small pool, additional samples are not necessary to characterize the spring because most turbidity settles out. It is likely the higher value recorded is due to sampler disturbance of the pool bottom.

5 DISCUSSION

With exceptions, drinking water quality standards are not exceeded. Total hardness is above the suggested levels for the entire sampling period. This elevated hardness is a direct result of the high calcium deposits in the proximity of the spring. Calcium exceeded the specified level on four occasions and as well, displays an increasing trend with time.

The response of calcium to harvesting activities is reported in various studies. Grier and Cole

(1971) and Grier (1975) found that burning increases leaching of Ca from the ash layer into the soil by rain or snowmelt. Grier (1975) further points out in spite of the leaching of cations of which Ca is one, that a large portion of the cations are retained in the soil at greater depths. Stark (1977) demonstrates a difference in Ca loss from soils depending upon the intensity of the burn -- the hotter burns result in net losses below the root zone. The cooler burns cause no transport of ions out of the root zone. It is generally agreed that calcium leaching following fire may increase (McNabb and Cromack, 1990).

At Strom Spring, it is difficult to attribute the increased calcium and related hardness and conductivity to the harvesting and site preparation activities occurring upslope. Firstly, the area of cutblock contributing to recharge is small given the total area of recharge for the spring. Secondly, calcium rich soils are located close to the spring and the cutblock soils subject to leaching had lower calcium contents. Higher calcium concentrations in the vicinity of the spring would effectively mask any changes in calcium concentration resulting from the leaching of calcium from exposed cutblock soils. Given the distance from the spring and the intensity of burn on that portion of the cutblock suspected of contributing to the spring it is unlikely that water quality impacts with respect to calcium occurred in the spring.

It is unclear what accounts for the significant increasing trend in calcium, hardness and conductivity over the sampling period. It is quite probable given a longer sampling period that these trends may not be significant. More research into the cation content of soil water on the cutblock and near the spring would provide answers to the movement of these constituents.

The other water quality parameter to note is iron. One measure of iron exceeded the specified level with all other measures well below. The presence of the intake pipe in the spring holding pond where the samples are taken may contribute to the presence of iron in the water but does not explain the one high measure.

A monitoring program of this nature points out several needs and limitations to evaluating the effect of harvesting activities on water quality. To fully assess impacts a research program with an adequate control is necessary. This requires sufficient lead time prior to harvesting activities to fully quantify available site nutrients and water quality. Monitoring programs can assess levels of impact but are limited in definitively predicting changes as a result of impacts. Monitoring programs can provide detailed information for evaluating the current conditions and whether they meet existing standards.

6 CONCLUSIONS

Significant increasing trends in calcium, hardness and conductivity are noted in a small spring near Crawford Bay B.C. over a two year monitoring period. Although the spring is located below a clearcut which was harvested and burned during the water quality monitoring period, it cannot be demonstrated that upslope activities are the cause of these increasing trends. It is highly possible that given a longer monitoring period, these trends are not significant. This study does

demonstrate that not all water sources meet specific drinking water guidelines. In this example, hardness is well above the standards and is a reflection of the type of water occurring on site. This study points out the need to document water quality for sources which may be affected by forest harvesting activities. This study cannot say anything definitive about harvesting impacts but does demonstrate that water quality did not change such that it exceeds drinking water standards.

APPENDIX 1. Summary of physical and chemical soil properties[1] from a site within the cutblock above Strom Spring.

Horizon	Bm	BC	C
Depth (cm)	0 - 35	35 - 68	68 - 100
Texture[2]	SL	SL	SL
% Sand	56.7	58.7	65.2
% Silt	39.6	38.7	30.8
% Clay	3.7	2.6	4.0
pH	5.7	5.4	5.4
C.E.C. (meq/100g)	5.9	3.7	3.7
Exch Ca (meq/100g)	2.92	1.41	3.20
Exch Mg (meq/100g)	0.16	0.16	0.16
Exch K (meq/100g)	0.21	0.15	0.10
Exch Na (meq/100g)	0.53	0.97	0.52
% Carbon	1.75	1.17	0.87
% Nitrogen	0.042	0.023	0.014
C/N Ratio	41.67	50.87	62.14

[1] analysis of soils by Griffen Laboratory, Kelowna, B.C.
[2] determined by hand texturing.

APPENDIX 2. .Complete chemical analysis from Strom Spring for all samples taken during the sampling period.

DATE YY.MM.DD	PH LAB	RESIDUE FILT (mg/L)	CONDUCTANCE (uS/cm) LAB	CONDUCTANCE (uS/cm) FIELD	TURB (NTU) LAB	ALKALINITY TOTAL 4.5 (mg/L)	HARDNESS TOTAL (mg/L)	NITROGEN ORGANIC (mg/L)	NITROGEN KJELDAHL (mg/L)	NITROGEN TOTAL (mg/L)	NITROGEN AMM (mg/L)	NITROGEN NO3+NO2 (mg/L)
86.10.01	7.4	246	438	404	0.6	212	214	< 0.01	< 0.01	< 0.03	< 0.005	< 0.02
86.11.03	7.7	246	452	390	0.8	219	230	< 0.01	0.01	< 0.03	< 0.005	< 0.02
86.12.01	7.9	210	360	341	0.4	185	198	0.05	0.05	< 0.07	< 0.005	< 0.02
87.01.05	7.7	212	380	320	0.5	182	198	0.05	0.05	< 0.07	< 0.005	< 0.02
87.02.02	7.9		385	297	0.9	184	215	< 0.02	0.02	< 0.04	< 0.005	< 0.02
87.03.02	7.7		392	344	0.4	183	210	0.07	0.07	< 0.09	< 0.005	< 0.02
87.04.01	7.8		360	310	0.6	169	183	< 0.01	0.01	< 0.03	< 0.005	< 0.02
87.05.04	7.6		389	341	1.2	187	206	0.05	0.05	< 0.06	0.007	< 0.02
87.06.02	7.9	216	418	309		195	216	< 0.02	0.02	< 0.04	< 0.005	< 0.02
87.07.06	7.9	230	433	352		205	207	< 0.02	0.02	< 0.04	< 0.005	< 0.02
87.08.04	7.8	236	445			215	225	0.05	0.05	< 0.07	< 0.005	< 0.02
87.09.01	7.9	234	450	400		214	221	< 0.02	0.02	< 0.04	< 0.005	< 0.02
87.10.05	7.7	232	450	381		214	223	0.04	0.04	< 0.06	< 0.005	< 0.02
87.11.02	7.8	240	450	370		215	222	0.04	0.04	0.04	< 0.005	< 0.02
87.12.01	7.8	238	435	387		210	216	0.07	0.07	< 0.09	< 0.005	< 0.02
88.01.04	8.1	232	443	365		198	216	< 0.01	0.01	< 0.03	< 0.005	< 0.02
88.02.03	7.8	224	420	454		192		0.04	0.04	< 0.06	< 0.005	< 0.02
88.03.01	8.0	206	395	343		180	203	0.07	0.07	< 0.09	< 0.005	< 0.02
88.04.05	7.9	196	360	306		163	174	< 0.01	0.01	0.03	0.006	< 0.02
88.05.02	7.7	216	390	339		183	213	< 0.02	0.02	< 0.04	< 0.005	< 0.02
88.06.02	7.7	226	420	358		194	205	< 0.01	0.01	< 0.03	< 0.005	< 0.02
88.07.04	8.0	240	440	387		201	221	< 0.02	0.02	< 0.04	< 0.005	< 0.02
88.08.02	8.2	244	462	392		206	237	< 0.01	0.01	0.03	< 0.005	0.02
88.09.01	7.5	264	470	392		210	264	0.04	0.04	< 0.06	< 0.005	< 0.02
88.10.03	7.7	252	447	364		216	233	< 0.01	0.01	< 0.03	0.006	< 0.02
88.11.02	7.1	196	373	400		171	218	< 0.01	0.01	< 0.03	< 0.005	< 0.02
MAX	8.2	264	470	454	1.2	219	264	0.07	0.07	0.09	0.007	0.02
MIN	7.1	196	360	297	0.4	163	174	0.01	0.01	0.03	0.006	0.02
MEAN	7.8	228	418	361	0.7	196	215	0.03	0.03	0.05	0.006	0.02
STD	0.2	16.6	32.8	36.7	0.3	16.1	17.2	0.0	0.0	0.0	0.0	
VAR	0.0	277.1	1077.9	1345.1	0.1	259.8	297.2	0.0	0.0	0.0	0.0	
COUNT	26	22	26	25	8	26	25	26	26	26	26	26
# <								15		24	23	25

APPENDIX 2. (Cont.)

DATE YY.MM.DD	CA (mg/L)	MG (mg/L)	FE (mg/L)	MN (mg/L)	FLOURIDE DISS (mg/L)	SULFATE DISS (mg/L)	POTASS DISS (mg/L)	PHOSPH TOTAL (mg/L)	N/P RATIO	SODIUM DISS (mg/L)	Na/K RATIO	CHLORIDE DISS (mg/L)	TEMP (oC)
86.10.01	68.9	10.20	< 0.01	< 0.01			2.1	< 0.003	10	1.6	0.8		10.1
86.11.03	76.1	10.30	0.06	< 0.01			2.1	0.004	8	1.7	0.8		8.8
86.12.01	64.8	6.73	0.01	< 0.01			0.6	0.003	23	1.3	2.2		7.8
87.01.06	64.1	9.12	0.03	< 0.01	< 0.1	13.9	1.8	0.005	14	1.3	0.7		7.9
87.02.02	69.7	9.86	0.01	< 0.01	< 0.1	14.2	1.8	< 0.003	13	1.4	0.8	0.6	8.1
87.03.02	67.7	9.89	< 0.01	< 0.01	< 0.1	14.0	1.6	0.004	23	1.1	0.7	0.6	8.3
87.04.01	59.5	8.42	0.34	0.01	< 0.1	12.5	1.6	0.003	10	1.2	0.8	0.5	5.9
87.05.04	68.7	9.47	0.03	< 0.01	< 0.1	13.3	1.8	0.003	27	1.4	0.8	0.5	7.9
87.06.02	68.9	10.70	< 0.01	< 0.01		14.5	2.0	0.003	13	1.4	0.7	< 0.5	7.8
87.07.06	67.8	9.27	0.05	< 0.01			2.0	0.004	10	1.5	0.8		7.8
87.08.04	73.5	9.98	0.05	< 0.01			2.1	0.004	18	1.6	0.8		10.0
87.09.01	72.1	9.97	< 0.01	< 0.01			2.2	0.005	8	1.8	0.7		10.0
87.10.06	73.3	9.78	0.03	< 0.01			2.1	< 0.003	20	1.7	0.8		9.5
87.11.02	73.7	9.34	0.01	< 0.01			2.1	< 0.003	13	1.7	0.8		9.5
87.12.01	70.9	9.46	< 0.01	< 0.01			2.0	0.003	30	1.8	0.8		8.1
88.01.04	70.3	9.83	0.01	< 0.01			2.0	0.003	10	1.8	0.8		7.3
88.02.03	71.1	9.82	0.02	< 0.01			1.9	0.003	20	1.4	0.7		7.0
88.03.01	65.2	9.71	0.02	< 0.01			1.8	0.003	30	1.3	0.7		6.5
88.04.05	55.9	8.41	0.02	< 0.01			1.7	0.006	5	1.2	0.7		5.8
88.05.02	69.8	9.29	0.07	< 0.01			1.8	0.003	13	1.4	0.8		6.8
88.06.02	67.5	8.91	0.09	< 0.01			1.9	0.003	10	1.5	0.8		7.6
88.07.04	72.5	9.63	0.02	< 0.01			2.0	0.003	13	1.7	0.9		10.0
88.08.02	78.1	10.2	0.01	< 0.01			2.0	< 0.003	10	1.7	0.9		9.5
88.09.01	88.1	10.8	0.03	< 0.01			2.1	0.033	2	1.6	0.8		9.8
88.10.03	76.0	10.4	0.02	< 0.01			2.2	0.006	6	1.8	0.7		9.9
88.11.02	70.7	10.1	0.04	< 0.01			2.1	0.007	4	1.5	0.7		9.0
MAX	88.1	10.8	0.34	0.01	0.1	14.5	2.2	0.033	30.0	1.7		0.6	10.1
MIN	55.9	8.4	0.01	0.01	0.1	12.5	0.6	0.003	1.8	1.1		0.5	5.8
MEAN	70.2	9.6	0.04	0.01	0.1	13.6	1.9	0.006	14.0	1.5		0.6	8.2
STD	5.9	0.7	0.1			0.7	0.3	0.0	7.5	0.2		0.1	1.4
VAR	35.4	0.4	0.0			0.5	0.1	0.0	56.9	0.0		0.0	2.0
COUNT	26	26	26	26	5	5	26	26	26	26		5	26
# <			5	25	5			5				1	

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